III.A.2 Metal Interconnect for SOFC Power Systems

S. (Elango) Elangovan (Primary Contact), Shekar Balagopal, and Insoo Bay
Ceramatec, Inc.
2425 South 900 West
Salt Lake City, UT 84119-1517
Phone: (801) 978-2162; Fax: (801) 972-1925; E-mail: Elango@ceramatec.com

DOE Project Manager: Lane Wilson
Phone: (304) 285-1336; E-mail: Lane.Wilson@netl.doe.gov

Objectives

- Select a surface treatment process for commercial ferritic stainless steel to reduce oxide scale growth rate.
- Optimize treatment process conditions to provide a conductive, stable scale.
- Measure the scale properties in solid oxide fuel cell (SOFC) relevant conditions.

Approach

- Select a heat treatment process to achieve a thin, dense scale of a conductive oxide composition.
- Measure scale conductivity in air at target operating temperature.
- Evaluate scale morphology under fuel cell operating conditions.

Accomplishments

- The surface treatment was found to reduce the scale growth rate as determined by thermogravimetry at 750°C. The treated metal coupons showed a parabolic rate constant of 5×10^{-9} $gm^2/cm^4/hr$, compared to 7×10^{-8} $gm^2/cm^4/hr$ for uncoated coupons. The low oxidation rate of treated interconnects will enable achieving the target fuel cell operating life of 40,000 hours.
- Scale resistance was 10 milliohm-cm^2 in air at 750°C and less than one milliohm-cm^2 in humidified hydrogen.
- Scale morphology was characterized as a function of treatment process and test conditions relevant to fuel cell operation.

Future Directions

- Optimize the surface treatment to mitigate the effect of simultaneous exposure to hydrogen and air on opposite sides of the metal interconnect.
- Evaluate chromium evaporation characteristics of the stainless steel as a function of surface treatment.

Introduction

Interconnects perform essential functions in a fuel cell stack: namely, electrical connection between adjacent cells and separation of air and fuel. In many cases, they also provide structural support for the stack. The use of commercial alloy offers the potential for low-cost interconnect components. This allows achieving the DOE target of low-cost, modular fuel cell stacks.

The SOFC interconnect must simultaneously satisfy several functional requirements. These functions require materials with high electronic conductivity for the series connection of individual single cells, gas impermeability to separate fuel and oxidant gases, chemical stability and conductivity over a large oxygen concentration range in order to maintain integrity in both the fuel and air atmospheres. Thermal expansion match with the rest

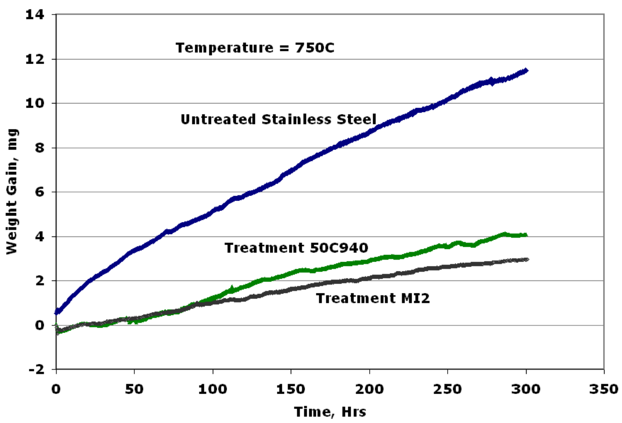

Figure 1. Thermogravimetry of Ferritic Stainless Steel Coupons

of the cell elements is desired. Metal interconnects are very desirable from the viewpoints of manufacturing cost in addition to other functional requirements, provided that the high conductivity can be maintained at the operating conditions. Metal interconnects also lend themselves to ease of fabrication of gas channels and greater control over dimensions to help improve the conformity as well as uniform reactant distribution to ensure uniform current density, high fuel utilization and high fuel efficiency. The use of thin metallic sheets will also reduce overall weight in the fuel cell system. High thermal conductivity of metal interconnects will help distribute the heat generated during the operation of the cell, thereby reducing the cooling air requirement as well as eliminating thermal stress failure of ceramic components caused by sharp thermal gradients.

The principal requirements of metal interconnects can be summarized as follows: 1) thermal expansion match with other cell components, 2) oxidation resistance in air and fuel at the operating temperature, 3) conductive interface (scale) in air and fuel atmospheres, 4) prevention of reactivity with electrode materials to form insulating compounds, 5) low volatility of major or minor constituents that poison electrode activity, 6) compatibility with anode and cathode environments, 7) uniformity in contact with the cells, 8) thermal cycle capability, and 9) low cost. The present work focuses on the development and

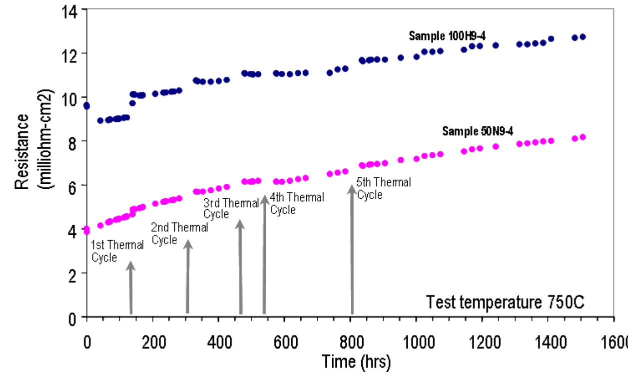

Figure 2. Resistance of Coupon Couples in Air at 750°C

evaluation of conductive oxide scale on commercial ferritic stainless alloys.

Approach

A commercial stainless steel alloy was selected. The surface oxide scale was modified using an appropriate coating and heat treatment process to provide a dense conductive oxide scale. The growth rate, resistivity, and morphology of the scale were determined as a function of time for the various surface treatment conditions. The evaluations were made both in single-atmosphere (air or fuel) or dual-atmosphere (air and fuel on the opposite sides) conditions.

Results

Thermogravimetry of a 400-series commercial stainless steel was performed. Both untreated and treated coupons were evaluated. Two types of treatments were done. The first one was to heat treat the coupon to grow a controlled, dense oxide scale layer (treatment 50C940). In a second variation, an additional treatment was done to provide a stable chromium oxide composition as the outer layer (treatment MI2). The comparison of the oxide scale growth, via weight gain, is shown in Figure 1. The pre-grown oxide layer was found to reduce the scale growth significantly, while the second treatment provided an additional reduction in scale growth rate.

The resistances of the coupons were measured after they were surface treated. Two coupons were sandwiched using a conductive perovskite (e.g., cobaltite) as the contact paste. The change in

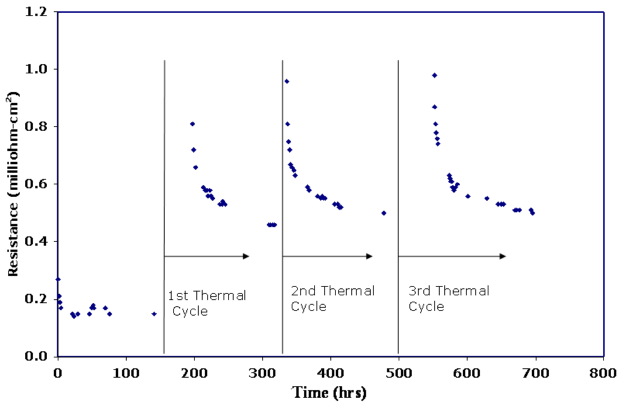

Figure 3. Resistance of Coupon Couples in Humidified Hydrogen at 750°C

measured resistance values of the coupon couples at 750°C in air is shown in Figure 2. The coupons were subjected to several thermal cycles. Similar measurements were also made in humidified hydrogen using nickel paste as the contact layer, shown in Figure 3. In both atmospheres, the resistance values were below 10 milliohm-cm^2, meeting the interconnect resistance target.

Earlier work showed that the oxide scale on the air side is disrupted when the opposite side is exposed to hydrogen at the target cell operating temperature. In order to evaluate the effect of dual-atmosphere exposure, resistance of a coupon couple was measured as one coupon was exposed to dual atmosphere. The test arrangement and the results of a test using the graded scale composition are shown in Figure 4. The low resistance measured under realistic exposure condition is encouraging although additional work is needed in characterizing possible change in scale morphology under such conditions.

Conclusions

- Surface treatment to commercial ferritic stainless steel is shown to reduce the oxidation rate in air at SOFC operating temperature.
- The resistance values of the stainless interconnect meet the target.
- Exposure to dual atmospheres disrupts the oxide scale on the air side, and the graded scale layer provides a promising approach. Further work is planned to evaluate the scale morphology. The work will also be extended to study the chrome evaporation from the interconnect that could poison the cathode during stack operation.

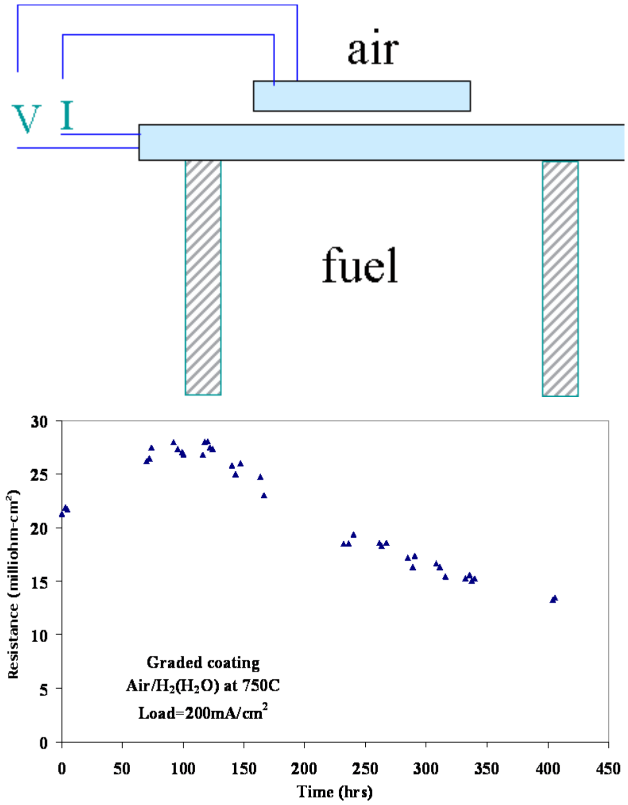

Figure 4. Test Configuration and Resistance of Coupon Couples in Dual Atmosphere

FY 2004 Publications/Presentations

1. "Evaluation of ferritic stainless steel interconnects for use as metal interconnects for solid oxide fuel cells," S. Elangovan et al., Journal of Materials Engineering and Performance, Vol. 13, No. 3, June 2004.
2. SECA Annual Workshop and Core Technology Program Peer Review Workshop, Boston, MA, May 2004.
3. SECA Core Technology Program Review Meeting, Albany, NY, September 2003.